# Auctioning airport slots (?)

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**Abstract**

The current allocation of slots on congested European airports constitutes an obstacle to the effective liberalisation of air transportation undertaken in Europe. With a view to favouring efficient slot utilisation and competition, as is the goal of the European commission, we propose to use a market mechanism, based on temporary utilisation licences. In order to allocate those licences, we propose and describe an iterated combinatorial auction mechanism where a percentage of licences would be reallocated each season. A secondary market would also be set up in order to reallocate slots during a season. Since a combinatorial auction involve a complex optimisation procedure, we describe how it can be made to work in the case of auctions.

**Keywords:** slots, airports, licence, auctions, combinatorial

## *Introduction*

Air transportation has been liberalised in the European Union in 1997, after a few years of transition. It seems, however, that so far, the effects on competition are not as important as they have been in the USA, after the deregulation in 1978.

One of the key factors impeding competition in Europe is the lack of airport capacity at major airports for takeoffs and landings. Because of this capacity shortage, in Europe authorities decided to limit the number of takeoffs and landings to a specified number per hour at certain airports corresponding to the runway capacity. A slot is then defined as "... the scheduled time of arrival or departure available or allocated to an aircraft movement on a specified date at an airport co-ordinated under the terms of regulation...".

In Europe, airport slots are allocated following the "grandfather rights" rule, which is the historic rule prevailing before liberalisation. According to this rule, an airline using a slot during one season keeps it for the following season, as long as the slot has been properly used ("use it or loose it" rule). Available slots are given as a priority to new entrant airlines. But since very few slots become available each season, this leads to a very conservative allocation.

This rule enables stability in the market but by preventing entry of new airlines, it falls short of the deregulators expectations to promote competition in the airline industry. In the following article, we consider the situation from the point of view of the European Community and we assume that the objective[1] is to favour efficient slot utilisation and competition[2].

It is therefore vital, from the European commission point of view to study alternative allocation rules, either administrative or market based rules, to prevent the liberalisation process from stalling

This is what this paper proposes to do, after reviewing the way the current processes (in Europe and in the USA) function, and the shortcomings of the current (part 1). We first examine the question of the nature and property of the slots, and propose to define the slot as a temporary utilisation licence (part 2). In part 3, we review the objectives of the slot allocation and justify the choice of a market mechanism for allocating slots.

One solution, the designing of auctions for slots is more thoroughly studied: auctions are presented and auction design discussed in part 4, and a possible mechanism based on combinatorial auctions is proposed in part 5.

In the conclusion, we review our findings and intuitions, and discuss the problem of acceptability of a market-based mechanism for allocating slots

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[1] Other political objectives could no doubt also have a role in the decision as to whether or not one slot allocation system should be adopted rather than another.

[2] The choice concerning the level of regulation or liberalisation of the air transport sector involves arbitration between the interests of the various groups of society, and we do not intend to enter this debate which seems to have been settled some time ago (although this in no way means that a political decision in the future cannot reverse the tendency, even though such a perspective seems highly improbable at the present time).

## *1-Airport slots today: the current system and its shortcomings*

The current system prevailing throughout the world for allocating slots (except in the USA for domestic slots, as we shall see later on), is the "grandfather right" rule. Basically, the outline of this system is the following: airlines are allocated the same slots each season, as long as they really use it ("use it or loose" it rule). In Europe this system is based on the EC rule 95/93 [règlement CEE n°95/93 du Conseil des Communautés Européennes]. It is not our goal to give a complete description of this system, but rather to outline its main features. For a more thorough description of this allocation system, see for example "allocating airports slots" [7].

The EC rule is an adaptation of the former pre-liberalisation system, and has been adopted to clarify the rules of allocation throughout Europe. Although it has harmonised the allocations throughout Europe, it fails to reach an economically efficient allocation, because slots are not attributed with the objective of maximising benefits for air services consumers or the economy.

Furthermore, despite the fact that a part of the available slots is reserved for newcomers on the airport, the European procedure for assigning slots on saturated airports constitutes an entry barrier and restrains competition. This is because, according to the grandfather rule, only a small number of slots are potentially reassigned to new airlines. Those not wanted by the incumbent airlines and those not properly used, falling under the "use it or loose it "rule, are put into a pool; half of the pool slots are then reattributed to newcomers. This amounts in general to very few slots each season.

In the USA, the grandfather right rule existed before deregulation on a few airports[3] (others being "self-regulated" through congestion). After the 1978 deregulation, the federal Authorities tried to find a new rule, more consistent with the objectives of deregulation.

They set up a system on four saturated airports, which assigned the property of the slots to the airlines, and allowed those airlines to sell their slots to one another (the 1985 "buy and sell" rule). The results of this experiment were not conclusive: The number of slots sold was relatively small, and the sales tended to increase concentration. This is not particularly surprising, since nothing was done to ensure that a large number of slots would be put up for sale and that the sales would favour newcomers. The reason for this is that, as the demand for slots is increasing on such airports, airlines are tempted to retain slots that they do not really need, either for later use or in order to be able to sell them at a higher price. Furthermore, for as long as there is no real possibility for airlines to enter the airport by directly acquiring a sufficient number of slots, it is hardly surprising that it is the airlines already there who buy up any slots that are up for sale.

Finally, if both systems have the advantage of succeeding in allocating slots each season, and provide airlines with a certainty over future allocation, they fail to allocate them efficiently, in a way that maximises benefits for consumers of air services. It is so mainly

[3] Four airports are concerned today : New York Kennedy, New York La Guardia, Washington National, and Chicago O'Hare

because they are rigid and prevents changes, they distort investment incentives[4] (by giving the slots for free and forever), and above all they allocate slots arbitrarily (no economic criteria).

## *2- Property rights, the slot as a temporary utilisation licence*

### *2.1 Property rights for slots*

In view of the currently imprecise legal aspect, some organisations - including airports - turn to the state for a more precise definition of who owns the property rights for slots. If such a question exists, and if it is up to the State to settle it, then the question is meaningless: Slots belong to the state de facto, and the state is entitled to give them away or sell them if it wants to. In view of the capital strategic importance of this type of asset, we feel that it is increasingly important that the state should retain these property rights and simply grant rights of use for certain specified periods [5].

The reason behind this debate is obviously to define who should benefit from the income connected with the possible sale of the slots. This question results from a political choice, and it is not up to us to give our opinion. However, assuming that the state decides that airports - for example - should benefit from the advantages connected with the use of slots, it would be preferable to set up a system which aims to assign the slots in an efficient manner, and then to enable the airports to benefit from the corresponding income, rather than giving them the property rights directly.

We should note, in passing, that if airports became the owners of the slots, they would not have any incentive to invest in an increase in their capacities, because they would not want to affect the income they would derive from the rarity of the slots. This comment remains valid if a decision is made to transfer the entire income of the auction to the airports. If the decision is made to give the benefit if the income generated by the slots to one of the players in air transport, every effort should be made to do this through fixed transfers, i.e. transfers which are not dependent on the income actually generated.

### *2.2 The slot as a temporary utilisation licence*

We saw that with the grandfather right rule, only a small number of slots are reattributed each season. Even in the case where all the slots of an airline are put back into the pool of slots to be distributed (which is the case of Air Lib in Orly), the current procedure consists in redistributing all the slots formerly belonging to a single airline to several other airlines, thus

[4] They can give incentives to invest for example in marginally profitable routes in order to keep the slots ("baby sitting" of slots)

[5] The usual argument used to justify transferring property rights for a resource from the state to a company is that it encourages the company to set up specific investments: If the company has no guarantee that it will retain the right to use the resource, it is unlikely to finance investments which are specific to that resource despite the fact that it would be efficient for society. In the context concerned herein, we nevertheless feel that this argument is of minor importance.

reinforcing the positions of the dominant airlines on the airport. Finally, if we consider the fact that there is often a minimum number of slots that an airline must obtain on an airport for that airport to be a cost-efficient destination (due to the frequency effect, for example), it is clear that for competition to be effective in terms of entry onto an airport, it is necessary to be able to reallocate, on a fairly regular basis, a considerable number of the slots on each airport.

This is why we recommend that the grandfather rule should be progressively dropped, that airlines should be given temporary licences to use slots[6] (5 to 10-year licences, for example), and that they should be allowed to sell those licences. Progressively, of course, because we must not upset the stability of a system which - although not perfect - does have the advantage of working. We could, for example, attribute 10 % of the existing licences every year for ten years (at the end of this period, the initially attributed licences would be due for reattribution, and so on). We are not giving any recommendation, at this point, concerning the method to be used for the initial allocation of the slots, as this will be discussed in subsequent chapters. We are simply pointing out that this procedure should make it possible for new airlines to obtain sufficiently large sets of slots to enable them serve the airport efficiently.

Furthermore, limited-period licences would encourage airlines to sell off the slots that they do not really need - or that other airlines could make better use of - rather than keeping them for the future.

To summarise, we recommend, above all, that temporary licences to use slots should be regularly reassigned, and that airlines should be allowed to sell them according to a system which enables new entrants to set themselves up properly on an airport.

## *3- The objectives of a slot allocation, choice of a market mechanism*

### *3.1 Objectives of a slot allocation*

Whatever system is used to allocate slots, it has to be judged by the benefits it brings to the economy. More precisely, the air services resulting from this allocation provide some level of "social welfare" to the customers and to the rest of the economy (including some profit to the airlines).

The optimal allocation is the one that brings maximum benefit for society. But it is not sufficient, because what is optimal at one point in time, may not remain so for long: the allocation should also be capable of evolving, in order to re-allocate the slots to the most efficient use.

Slots are efficiently allocated when used by the airlines that can generate maximum social benefit from them. We can consider, in a competitive situation, that if an airline thinks it will make large profits by using a slot, this fact tends to indicate high demand and low costs, and therefore a high profit is a reliable indication of a large social benefit.

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[6] This is only an example, and studies should have to be conducted, as to the optimal proportion of slots to attribute each season, and how to select them. We feel however, that the right duration would be between 5 to 10 years, so that 10 to 20 % of seasonal slots should be reattributed each season.

In order to approximate this optimum, we can then target the intermediary goal of maximising the profit airlines derive from the use of a slot[7], which is linked to the willingness to pay for the slot by the airline.

A market mechanism with prices for slots would achieve this requirement, as long as the price reflects the willingness to pay for the slot. There comes in the problem of the revelation of the value of the slot for the airline, problem which could be solved, as we shall see later, by an auction mechanism.

In reality, the social benefits may not be maximised when profits are maximum, for different reasons: there can be conditions of limited competition, when an airline on a market has some market power, and uses that situation to raise prices, resulting in a decrease in social welfare. The allocation system chosen should therefore address this problem by preventing the building of market power.

Another potential problem is that airlines do not take into account the benefits for society of serving for example one regional market when demand does not reflect the importance for the economy of that particular market (there are external benefits not reflected in the demand on the route). This can lead to adaptations in order to take those external effect into account.

Finally, there is an equilibrium to find between the adaptability of the system to changes in demand or market conditions, and a stability necessary to the good functioning (return on capital) and development (investment incentives) of the airlines. With respect to stability, the established airlines currently favour the "grandfather right" system, which gives them a large degree of certainty over the future holding of slots. They may therefore be reluctant to adopt a new system whatever its qualities. We shall come back to the point of acceptability of a new system in the concluding section.

### *3.1 Advantages of selling slot utilisation licences*

The European procedure for assigning slots on saturated airports is characterised by the fact that it is free of charge. Among the disadvantages of this procedure, the most obvious is the disproportion between the demand for slots and the slots that are actually available. Because of the information asymmetry between the authorities in charge of assigning slots and the airlines, it is difficult to assess which airlines will use the slots in the best manner as far as society is concerned.

Furthermore, due to the complexity of the problem, any administrative-type procedure is likely to lead to an inefficient situation in which certain slots are not allocated to airlines which are capable of valorising the situation.

A solution could therefore consist in selling a temporary licence to use slots. The most basic way of doing this consists in setting a price (possibly variable, depending on the time of day of the slot) whilst retaining the current procedure. Initially, this would reduce the demand for slots and consequently the risk of mistakenly attributing slots to companies which do not valorise them as much as others would. But this solution, which is the easiest to implement,

[7] not taking payment for slots into accounts

only partially solves the problem of asymmetrical information[8], and it does not solve the problem of entry barriers.

Economists tend to prefer the auctioning solution, which has the advantage (when well designed) of revealing private information held by airlines and favouring the possible entry of new airlines on airports. With this in mind, the objective is not to generate funds but to use the information based on how much an airline is prepared to pay as an indicator of the profits it expects to draw from operating that slot[9]. In this context, an auction would aim to assign a slot to an airline which considers that it can obtain the highest profit in exchange for a part of that profit.

We will also see that it is perfectly possible to design the auction in such a way that it takes into account factors that could appear to be important from a social point of view, but which would have no effect on the profits of the airlines or that they would not take into account. It is possible for example to reserve slots for regional services as it is done today.

However, the results can be catastrophic if the auction is not properly designed. And in the present case, there are so many assets to be allocated, and those assets have such high synergy, that we can expect a traditional auction to generate a number of perverse effects.

But to discuss auctioning a large quantity of assets without defining the rules of the auction is not particularly significant, because the designer of the auction has a very large number of parameters that can be adjusted and fine-tuned, all with very different effects.

As far as putting slots up for sale is concerned, we insist on the fact that there are systems which can considerably improve the efficiency of allocation. Even if we do not set up an auction system, which can be a complex matter, we could at least set up a variable price system without taking any risks, based on the time of day and on the estimated demand for slots at that time of day[10].

### *3.2 Market mechanisms and the survival of "reasonably" sound companies*

The UMTS auctions that have been held in some countries are sometimes criticised for having played an important part in the financial ruin of a number of mobile telephone operators. Agreed, certain companies made astronomical bids in order to obtain a UMTS licence, but this is only the consequence of (now apparently) unreasonably optimistic forecasts made by those companies concerning the future of the sector. Those forecasts were furthermore expressed in the form of an incredible wave of acquisitions at considerably overvalued prices: Even if the auctions had not taken place, the situation would not have been

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[8] According to economic theory, in order to solve the problem of risking an attribution of slots to the "wrong" airlines, it would be necessary to find the prices for which demand equals supply, but this is impossible due to the very existence of asymmetrical information. And if we attempt to assess those prices in an aggressive manner, by trying to come close to the estimated limit prices, there is a risk that some of the slots - specifically the most sought-after - might not be attributed to anyone.

[9] In reality, the objective is not to maximise the profits of airlines, but rather the social surplus, defined as the difference between what consumers would be prepared to pay for a service and the costs induced by the production of that service. But we can consider, in a competitive situation, that if an airline thinks it will make large profits by using a slot, this fact indicates high demand and low costs.

[10] If we want to avoid taking risks, this system could be set up progressively, changing the prices cautiously over a period of about ten years, for example.

very different. In the context of air transport, which has a longer history than new information technologies, one can expect a little more moderation on behalf of airlines.

The fact that market mechanisms enable governments to raise funds generates criticism towards those mechanisms. However, it is necessary to raise revenues in order to achieve efficiency, since the revenues raised are the indication of the market value associated with the asset.

Nonetheless, the sale of slots creates a new cost item in a sector which is not in particularly good health. We can nevertheless establish certain measures which aim to reduce the impact of these costs.

First of all, the auction price or selling price can be based on the amount that the airlines are prepared to pay each month - for example - to obtain a slot. It is also possible to index the payment determined by the auctioning process on the level of activity of the sector, or on other indicators.

Finally, the income generated by the auctions can be used for the benefit of the airlines themselves. For example, the money could be used to finance an insurance fund [11]. But it is important that any support provided to an airline as a result of the collected funds should be as unrelated as possible to the amounts actually paid by that airline, in order to avoid distorting the bids made by the airline during the auction.

## *4 - Auctioning slot utilisation licences*

In this section, we will present an auctioning system which theoretically enables an efficient situation to be reached, and which has certain very interesting characteristics. We also propose a few possible changes to this system, that we consider viable and interesting.

### *4.1 Choosing an auction mechanism*

As regards auctions, several mechanisms can be designed, with different properties. Concerning slots, there are specific issues to be addressed by the auction mechanism chosen. We believe that the most important of theses issues is the aggregation problem: a specific combination of slots has more value for an airline than the sum of the individual values of slots. This is true between airports (we shall come back to this point later on), but also inside an airport: the hub and spoke organisation of networks, with arrival and departures concentrated in time, makes it important for an airline to have certain sets of synergetic slots.

With simple auctions, where assets are auctioned separately, airlines may fail to obtain all the slots they need and may end up with an inefficient allocation (from the point of view of their operation).

In order to reduce, or solve the aggregation problems, two main designs can be used: the first one is a simultaneous, multiple rounds auction (SMRA). The Federal Communication Commission (FCC) has used it for the spectrum auctions in the USA, with reasonable success. Basically, it allows firms to bid on individual assets, the auctions are held simultaneously for

[11] This possibility is mentioned for the purpose of information: In the long run, the question of using the funds collected by the auction is actually a political choice, and it is not up to us to give our opinion.

all assets, and repeated as long as necessary so that nobody wants to change its bid. Assets are only allocated at this point.

DotEcon, in its January 2001 report [7], proposes a SMRA for the airport slots allocation, relatively close to the FCC procedure.

This mechanism alleviates the aggregation problem, but does not solve it entirely, because auctions are simultaneous but still separate. Bidders can not bid on bundles of slots and therefore may still face some aggregation problems.

Another way of solving this problem is the use of combinatorial or "package" bidding where bidders can bid on multiple bundles of slots. They obtain a whole package or nothing. This is what the FCC is currently experimenting with. By enabling bidders to bid on packages, this kind of mechanism eliminates the aggregation problem entirely.

Since we feel that the aggregation problem is an important issue with the slot allocation, we shall turn to a combinatorial bidding procedure, although this kind of auction is more difficult to implement.

## *4.2 An efficient mechanism: Vickrey-Clarke-Groves auctions*

### 4.2.1 Definition

Among the mechanisms invented by economists to allocate rare assets, the Vickrey-Clarke-Groves mechanism ([24], [3], [8]) has a remarkable property: Whatever the strategies of the other buyers, the optimum strategy of any given buyer consists in bidding, without lying, the maximum value that he/she would be ready to pay for any bundle of assets.

To obtain this result, it is simply necessary for each buyer to have a reliable knowledge of the value that the auctioned asset or combination of assets will have for him/her if ever he/she were to obtain them. [12].

The Vickrey-Clarke-Groves mechanism allows for combinatorial bids: Bidders can submit bids for multiple combination of assets rather than just individual assets.

This mechanism operates as follows: Each player is asked to bid the maximum value that he/she would be prepared to pay in order to see each of the "states" of nature implemented (here, the state of nature represents the allocation of the auction: an identification of all the assets that each buyer obtains). The assets are then distributed according to the optimum allocation: This is determined by maximising, out of all the possible allocations, the sum of the values of the bundles assigned to the buyers on the basis of their bids. Finally, each buyer pays the seller the difference between the sum of the values of the allocation that would have been optimum if he/she had not taken part in the mechanism, and the sum of the values of the effective allocation for the other buyers (each buyer pays the seller what he/she costs the others - in terms of optimum allocation value - by taking part in the auction). For further details concerning this mechanism, the reader can refer to the book by V. Krishna [9].

[12] Other theoretical contexts lead to different results, but in practice one can consider that only a VCG mechanism would have good properties in terms of efficiency of the allocation for the slot allocation problem.

### 4.2.2 Illustration

As an illustration, imagine that 3 assets A, B and C are up for sale, and that 4 potential buyers are ready to buy them at the following prices:

| | *A*1 | *A*2 | *A*3 | *A*4 |
|---|---|---|---|---|
| A only | 2 | 5 | 4 | 3 |
| B only | 3 | 1 | 3 | 3 |
| C only | 6 | 3 | 2 | 4 |
| A and B | 8 | 6 | 10 | 8 |
| A and C | 8 | 9 | 7 | 7 |
| B and C | 10 | 4 | 10 | 8 |
| A and B and C | 14 | 13 | 14 | 12 |

With a Groves mechanism, buyer A3 obtains assets A and B and buyer A1 obtains asset C - which maximises the value of the assets obtained by the buyers, 16 in this case).

To determine how much buyer A3 must pay, it is necessary to observe what the maximum value of the assets obtained by the buyers would be if A3 didn't take part. In this case, buyer A1 would obtain B and C, and buyer A2 would obtain A, making a total value of 15. In the end, A3 must pay 15 - 6 (where 6 is the value of the assets obtained by the other buyers - A1 in this case - when A3 takes part), i.e. 9.

To determine how much buyer A1 must pay, it is necessary to observe what the maximum value of the assets obtained by the buyers would be if A1 didn't take part. In this case, buyer A3 would obtain B and C, and buyer A2 would obtain A, making a total value of 15. In the end, A3 must pay 15 - 10 (where 10 is the value of the assets obtained by the other buyers - A3 in this case - when A1 takes part), i.e. 5.

Another illustration: for auctions concerning a single asset, the highest bid wins the asset, and in this case the buyer pays the second highest bid.

### 4.2.3 Properties

This mechanism has two very interesting properties. The first has already been mentioned: Whatever the bids made by the other buyers, every buyer stands the best chance if he/she bids his/her true values for each bundle of assets, and this implies that the allocation is efficient. This is a classic result so we will not provide any further demonstration.

Furthermore, it is possible to add distribution constraints to this mechanism, without losing the previous property. So if we decide for example that at least 70 % of the slots must be attributed to European airlines, we retain the property according to which airlines are well advised to make bids which are equal to their true values, provided that the payment rule is adapted so that payment is calculated on the basis of the optimum allocation under this constraint[13].

[13] Technical comment concerning the payment rule in VCG mechanisms with allocation constraints: To calculate the payments, it is necessary to determine, for each buyer who obtains slots, what the optimum allocation would be, under the constraints, if that buyer did not take part in the auction. This could pose problems: For example, if the allocation constraint is that at least 4 buyers must obtain 4000 slots each, then if only 4 buyers take part in the

### *4.3 The combinatorial explosion problem, and how to restrain it*

In practice, if slots are defined as they are today, it is not possible to set up this type of mechanism for selling slots because the number of combinations of assets increases exponentially with the number of assets put up for sale ($2^n$ possible combinations if $n$ assets are put up for sale). The real problem is not, in fact, the number of bids that the buyers would have to place: After all, one could easily leave it up to the airlines to decide the level of complexity of their bids, which would obviously not cover all the states of nature. The problem is above all connected with the calculation of the optimum allocation and of the payments, which becomes problematic as soon as the number of assets up for sale becomes excessive.

Tuomas Sandholm ([22], [23]) has been working on this problem for a few years: He has already designed an algorithm to calculate the optimum allocation and the corresponding payments as quickly as possible. We can currently estimate that it is possible to implement a VCG type mechanism for as long as the number of assets to be allocated does not exceed a few hundred[14].

We shall see that by redefining the slot, we can limit the number of assets significantly, without loosing flexibility in the bids

#### 4.3.1 Definition of the asset to auction

The slot is the right to use airport capacity, and can thus be defined with this in mind. So far, the slot is defined as "...the scheduled time of arrival or departure...", and the sum of slots in a day matches capacity.

From an operational point of view, there is a 15-minute time window corresponding to the slot time, during which the airline is supposed to leave or arrive at its stand.

From an auctioning point of view, things can be seen with the same perspective, and the asset could be defined as "the scheduled time of arrival or departure, within a specified time window". Within a time window, there would be many slots, but they would all be the same from an auctioning point of view. This reduces considerably the number of assets to be auctioned, even with only a 15-minute time window. Furthermore, this is coherent with the operational constraints in an airport, and would not change fundamentally the current situation from the point of view of the airline operations.

However, this would not be sufficient to reduce the number of slots to the level necessary for solving the optimisation problem.

For example, let us take an airport operating 16 hours a day, with 100 takeoffs or landing a day. This amounts to 584 000 slots per year. By defining a 15-minute time window,

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auction it will not be possible to determine what the optimum allocation would be without one of the buyers, because there would only be 3 buyers left. To solve this problem, we can consider that there are also virtual buyers (as many as necessary) who assign a value of 0 to each bundle of slots.
With this payment rule, the best interest of the "real" buyers is still to bid their true values.

[14] He has also developed a logical language which enables buyers to describe their bids using a program, which means that it is not necessary to explicitly define the list of all bids.

one comes to a number of assets of 23 360. If we sell 10 to 20 % of seasonal slots each season, this amount to a number of assets between 1 168 and 2 336.

We may still have too many assets to calculate the optimal allocation, and we need therefore to envision some additional methods, in order to reduce the number of assets.

The following are a few examples of methods which can be used to adapt a VCG mechanism so that the number of calculations involved can be completed in a reasonable amount of time, but they have a cost in terms of efficiency and we point out some of the disadvantages of these adaptations.

### 4.3.2 Auction a few hundred predefined groups of slots

The first possibility consists in grouping the slots into coherent sets of slots, in such a way as to obtain a few hundred groups[15] at the most. This grouping must be carried out in such a way that the groups are coherent in terms of synergy between the slots they contain (every opportunity to use historical data should be taken, when defining the groups). After proceeding in this manner to reduce the number of assets up for sale, they can be sold using a VCG mechanism.

The most obvious grouping of slots, is the grouping of slots throughout the season. We would obtain a slot for a time window specific to a day during the whole season.

This procedure is obviously not perfect in the sense that, although the airlines are always well advised to bid their true values for the various groups of slots, the optimum reached is nevertheless an optimum under constraint: all the slots in a given group are allocated to the same airline. However, since most airlines operate on a regular basis throughout the season, this would not be a problem, except for part season operators (charters). This can be dealt with by the existence of a second market which could enable these inefficiencies to be corrected[16] (provided that the assets sold are time-limited operating licences - and this is an essential point).

Illustration: We come back to our preceding example (584 000 slots), and group slots for a season. Without using time windows, we find a number of slots of 11 230. Auctioning between 10 to 20 % of slots each season, We find between 1 123 and 2 246 groups. Adding time windows enables to reach a level of complexity low enough to solve the optimisation problem in a reasonable time.

### 4.3.2 Iterate several auctioning rounds, limiting the number of bids by each airline at each round

Another possibility would be to hold several rounds of auctioning. At the end of each round, the allocation would be calculated using a VCG mechanism and the results (and possibly the bids submitted) would be announced to the airlines[17]. The airlines could then

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[15] We shall call « groups » the sets predefined by the auction organiser. The sets chosen by the bidders we call « bundles ». In a combinatorial auction with predefined groups of slots, bidder can bid on bundles of groups of slots

[16] One could also provide for the individual sale, in parallel, of some slots for non-regular flights.

[17] Milgrom et Weber [17] suggest that it would be interesting - in terms of efficiency and even of income generated by the auction - to give the buyers as much information as possible concerning the bids made by their

make new bids during the next round, at the end of which the allocation would be recalculated on the basis of the bids made during all the rounds since the beginning of the auction. The idea would then be to encourage airlines to integrate the history of bids already made into their calculations, in order to avoid making bids which would not enable them to obtain slots, with the objective of limiting the calculations that need to be processed. With this in mind, it would be better if the airlines started by making bids, from the outset (i.e. the first rounds), for isolated slots or for small groups of slots[18]. Conversely, several individual bids for slots would immediately make it useless for anyone to bid for the complete bundle at a lower price than the sum of all the individual bids).

One major difficulty in designing iterative auctions is connected with the design of the rules for keeping the auction active or closing it. In other words, under what conditions does the auction end, and under what conditions does the buyer have the right to continue making further bids? The objective, here, is to limit any wait-and-see strategies on behalf of buyers, so that the auction closes after a "reasonable" time[19]. As an example, during auctions held by FCC to sell licences for using the Hertzian spectrum, the buyers were given a limit on the number of bids they could make at each round. This limit was determined on the basis of the number of bids they had made during previous rounds: A buyer who makes very few bids during a given round therefore loses the possibility of making a large number of bids during subsequent rounds. Obviously, for this to make any sense, the buyers must be prevented from making bids which are purely symbolic. (For a detailed analysis of the solutions and results concerning the auctioning of the Hertzian spectrum, refer to [4], [5], [12], [13], [15], [16]). We could use this type of rule here, possibly with an additional obligation to only make bids for individual slots (or small bundles) during the first rounds.

### 4.3.3 Limit the form of the bids that can be made by airlines

A final possibility, which enables the allocation calculations to be simplified considerably, consists in limiting the form of the bids that the airlines can submit. For

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rivals. In the case where the values of the various buyers are affiliated, i.e. the same case in which the VCG mechanism no longer necessarily yields the optimum allocation, the phenomenon observed can sometimes turn put to be what is known as the Winner's Curse: the one who wins an asset is the one who had the highest estimation of the value of that asset. This results in the fact that his/her estimation is biased, and it is likely to have been overestimated. Bearing this phenomenon in mind, buyers tend to adopt more prudent strategies which can cause the auction to yield less income, and the allocation to be inefficient. By running an auction in several rounds, between which the bids made by the buyers are made public, the buyers may be able to refine their estimation of the value of the assets and thus reduce the winner's curse.
Conversely, this reinforces the risk of collusion between airlines. Although it is true that collusion reduces income, it does not normally reduce the efficiency of the allocation, and our principal quest is the latter.
The issue as to whether the bids or only the results of each round should be made public is a complex one, and we shall not enter into a discussion on that subject here.

[18] whatever the amount of a bid made by a buyer for a bundle, another buyer could hope to obtain a part of that bundle even by making a very low bid, if a third buyer happened to make a high bid for the other part of the bundle

[19] This type of auction would then similar to the RAD mechanism designed by Kwasnica et al. ([10]).
The differences between the two are that, in this case, the mechanism makes buyers who win bundles pay the exact price that they bid for those bundles, and it does not limit the buyers' bids to individual assets during the initial rounds. Experiments carried out by these authors tend to show that this type of mechanism can have interesting properties in terms of efficiency.

example, if 30,000 slots are up for sale, and if one considers that an efficient allocation consists in allowing 4 airlines to hold coherent bundles of at least 4000 slots, it is possible to simply authorise the airlines to make bids[20] concerning (exactly) 4000 slots, 1000 slots or a single slot. The optimum allocation would, in this case, be determined under the constraint that at least four different airlines would obtain the bundles of 4000 slots they had bid for.

Conversely, with this system, it is not necessarily in the airlines' best interest to make "honest" bids which correspond to the values that they actually assign to the slots or bundles of slots. This is because there will be complementarities between slots that cannot be declared as belonging to the same given bundle of 1000 or 4000 slots. The airlines' strategy will therefore have to take into account the existence of these complementarities between assets which have not been requested in the same bundle, and the amounts bid for a bundle will no longer correspond solely to the value assigned to the bundle by the airline. Under these conditions, it is apparently no longer of any interest to adopt the VCG payment rule. It would no doubt be more pertinent to hold simpler auctions, similar to those held for the Hertzian spectrum in the United States (several rounds, and the sum of the amounts bid is maximised in order to decide on the optimum allocation. Each winner pays the exact amount of the bid he/she made), whilst retaining the possibility of making bids for bundles of 1000 or 4000 slots.

This possibility is therefore of less interest than the ones presented before, and we shall not take it into account in the final auction mechanism we detail in the next section.

## *5 - A proposed auctioning system*

### *5.1 Description of the auction*

Considering the advantages and disadvantages that we have discussed, we feel that the following mechanism could provide some interesting results.

The assets for sale are defined as licences to operate slots for a period of $n$ years ($n$ being between 5 to 10). Every year, (100/$n$) % of the slots are put up for sale (10 to 20 %, corresponding to the duration chosen). After the auction, the airlines are entitled to sell their licences.

On each airport, the slots are grouped by the auction organiser into a certain number of groups which appear to be coherent from a historical point of view (the most probable coherent grouping being seasonal grouping), and time windows are defined (in such a way that there are only a few hundred groups of slots on each airport).

Then, iterated VCG (open) auctions are held on all the saturated airports, possibly with distribution constraints (for example: at least 4 different airlines must obtain more than a certain quantity of slots[21], or at least a certain percentage of slots is distributed to newcomers on the airport). The bids of the previous rounds are sustained during subsequent rounds. A rule for continuing the auction and a rule for closing it (similar to those used for auctioning the

[20] As many as they wish.

[21] Which provides a form of insurance against excessive concentration.

Hertzian spectrum in the United States) are set up, and the bids concerning the first rounds of the auctions can only apply to individual slots.

Payments are determined on the basis of a monthly amount to be paid, calculated from the bids made by the airlines, using the rule of payment of a VCG mechanism with constraints. These payments are weighted according to the air transport activity level, on the basis of a rule announced at the beginning of the auction.

Some of the slots might not be auctioned, in order to be able to allocate them using other criteria. For example the government could keep slots for specific routes, as is already done currently.

After the auction a secondary market would be set up, ensuring efficient reallocation throughout the season. Since the organiser of the auction had to group the slots into groups of seasonal slots, the secondary market would enable airlines to obtain part season slots. Care should be taken as to the design of this market, in order to ensure that no building of dominant position could happen, as was the case on the US market for domestic slots.

### *5.2 Interaction between airports*

For the time being, we have only discussed the problem of allocating slots within a single airport. There is obviously complementarity between the slots of the same airport, but the complementarity is even greater between certain slots of different airports. This is because, if an airline wants to set up a flight between two saturated airports, it will need to obtain a slot at each airport at compatible times. In theory, the ideal solution would be to hold a single global VCG auction, covering the slots of all saturated airports. But this would not be possible, if only for technical reasons concerning the combinatorial explosion. There is nevertheless still the possibility of holding separate auctions on each airport.

How should these auctions be held? If they are held sequentially, the airlines will be faced with one of the major problems of separately auctioning interdependent assets: the problem of aggregation risk.

This is because the airlines will initially do everything they can to obtain slots on one airport, without knowing whether or not they will succeed in obtaining the corresponding slots on other airports. In this situation, the strategies used by airlines become very complicated. The random factors that face the airlines are considerable, and it will probably be hard to obtain a coherent set of slots from one airport to the other.

From our point of view, it would be preferable to hold these auctions simultaneously, in several rounds, so that the airlines can adjust their bids on one airport based on the results obtained on the other airports[22]. It would require a European co-ordination.

It is not clear whether a single airport (or country) could find advantages in implementing a market mechanism alone, because of the complementarity problem, but also for another reason, the possible distortion of competition between European airlines.

An isolated auction could indeed disadvantage the national airline hubbing at this airport, in its competition with the other national "hub" airlines. This could prove politically unacceptable, as it would upset a fragile competition equilibrium. Solutions could however be

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[22] For further details on this subject, refer to the debates on the form to be given to auctions of the Hertzian spectrum in the United States, [4], [5], [12], [13], [15], [16]

implemented to alleviate this problem. One would be to run the auction under the constraint that national airlines (or all airlines using the airport) eventually obtain the same proportion of slots as they have today. Another would be to compensate for the extra cost to the airlines using that airport (through an airport fee decrease for example[23]). Both systems could be combined and could be used as a temporary mechanism, in order to wait for the generalisation of the market mechanism.

Still, ideally, we think that a new system should have to be Europe-wide.

### *5.3 Strategic links*

As we are concerned with efficiency, one of the major risks is that no airlines succeed in obtaining the slots they require in order to set up an important link between two saturated airports (or that the number of links set up is too small) or one saturated airport and a regional one (regional service).

We can nevertheless adapt the preceding mechanism in order to protect the system from this risk. For example, if we are worried that there might be an insufficient number of links between Paris and Madrid, and we want to ensure that the slots distributed in a given year for Paris-CDG and Madrid are used to provide at least one return link between these two cities every day, the mechanism can be modified in two ways:

The first possibility is to allow the airlines to designate some of the slots in the bundles they are bidding for as "Paris-Madrid" or "Madrid-Paris" in the auctions concerning Paris-CDG and Madrid. The allocation of the auctions on each airport is then determined using the constraint that at least one slot per day must be designated "Paris-Madrid" and another must be designated "Madrid-Paris". This constraint can make it easier for airlines to obtain the slots concerned. In exchange, the licence to use these slots must be used for the corresponding link; otherwise the airline will be given a heavy fine or will have its licence withdrawn (even if it is subsequently sold to another airline).

Having said this, the adaptation described above does not entirely solve the problem because it may still be difficult for an airline to obtain both the slots corresponding to a given flight in the case of two saturated airports. Conversely, this procedure enables airlines to determine at what time of day the flights will take place, based on their information concerning demand.

The second possibility consists in arbitrarily grouping together, in a single groups, two slots which enable a Paris-Madrid link to be set up (one on each airport), and putting this "Paris-Madrid" group up for sale either in the Paris-Roissy auction, or in the Madrid auction. Here again, the corresponding licences would come with an obligation to use the slots for the "Paris-Madrid" link, otherwise there would be a heavy fine or the licences would be withdrawn.

This adaptation solves the problem of bringing together complementary slots on both airports. Conversely, it is less flexible because the time of day is imposed on the airlines.

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[23] As we already emphasised, this decrease in airport fees should be independent from the revenue generated by the auction, in order not to distort the bidders' strategies.

It is somehow close to what is done currently, with the "grandfather rights" system, where governments can reserve a proportion of the slots for regional services.

It should nevertheless be noted that both these adaptations could have adverse effects on the competition factor. This is because the allocation of a route-related licence to an airline makes it credible for that airline to operate that link and this might restrict any incentive that other airlines have to compete on that route. For this reason, we recommend that these adaptations be used sparingly (to guarantee a minimum number of essential links, without covering the full quota of passenger demand for the routes concerned).

### *5.4 Market power*

Since one of the primary goals of the slot allocation is to promote competition, the mechanism chosen should be capable of addressing the issue of market power. Rules should be devised that prevent too much concentration on routes, even if no direct relation systematically exists between concentration and market power on routes.

To this effect, constraints could be placed on the concentration level authorised overall or on a route, and integrated in the auction mechanism, or dealt with afterwards, on the secondary market. Such constraints should also be taken into account in the secondary market. It is beyond the scope of this paper to develop this subject in a more extended way, as it is a matter for competition legislation.

## *Conclusion*

After reviewing the shortcomings of the current slot allocation procedure in Europe, we have proposed a market mechanism, based on temporary utilisation licences, allocated through an iterated combinatorial auction.

It is one among many possible (auction) mechanisms, but we believe it has interesting properties in terms of efficiency and flexibility. We saw that adding constraints to the allocation is always possible without distorting the optimal strategies of the bidders, which is to announce their true values for each bundle of assets, implying that an efficient allocation is obtained. We also saw that should we need to reduce the computational complexity induced by the mechanism, it is preferable to predefine groups of slots rather than limit the form of the bids.

Several parameters of the mechanisms remain to be specified, like the duration of the licence, or the time window defining the slot, but overall, this mechanism should allow for a much more efficient use of the slots than today.

As we pointed out, ideally, such a mechanism should be implemented at the European level, in order not to distort competition between European airlines, and so that airlines can constitute coherent sets of slots between congested airports.

A point we did not develop in the paper but needs careful consideration from a practical point of view is the acceptability of this system. As mentioned, any new system would find hostility on the part of the established airlines, since it would imply taking from them what

they get nowadays for free, and consider to be part of their assets. Other airlines would be more favourable to a new system, if it enables them to gain access to so far unreachable airports.

Among new systems, one that solves the aggregation problem (the problem for an airline of not obtaining a coherent set of slots) like the one we proposed, is likely to be seen more favourably than one that does not address this problem.

Overall, the system of air transportation prevailing in Europe today is still one of national airlines. A new slot allocation mechanism would allow for (gradual) changes in that system, which may or may not seem acceptable from a political point of view, considering the social implications (what consumers could gain from more competition could be lost by workers, for example). The desirability of having a national airline is however a political issue, which we can only mention but not solve.

We are not claiming that our proposal is final, we are simply trying to contribute to a debate on the feasibility, the risks and the interest of such a procedure. We are in the process of designing a computer program to simulate competition between airlines, in order to launch an experimental economic program to compare the consequences of this mechanism with those of different modes of allocation.

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